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Sensory Characteristics of Lampung Robusta Coffee Beverage with Botanical Pre-Soaking Treatments

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Abstract— Botanical pre-soaking method has emerged as a potential approach to enhance the commercial value of Robusta coffee. This study evaluated botanical pre-soaking treatments using cinnamon (*Cinnamomum burmannii*), ginger (*Zingiber officinale*), tamarind (*Tamarindus indica*), and their combination, followed by traditional roasting, to modify the sensory profile and perceived quality of Lampung Robusta coffee, with emphasis on aroma complexity, flavor quality, and sweetness-associated attributes. Sensory profiling was conducted using Check-All-That-Apply (CATA), ideal-profile, and consumer liking analyses. Cochran's Q test revealed no statistically significant differences across all 34 evaluated CATA descriptors ($p > 0.05$), indicating primarily descriptive frequency variations. Treatments had limited effects on color, body, and aftertaste, but generated distinct descriptive variations in aroma and flavor while retaining nutty, chocolate, and earthy Robusta notes. Tamarind-treated coffee exhibited a complex profile with fruity, caramel-like, roasted, and warm-spice notes, positioning directionally closest to the ideal profile. The ideal profile was associated with fruity, caramel, sweet, chocolate, and cinnamon notes, whereas consumer liking was driven by a balanced combination of sensory attributes rather than individual note dominance. Overall, botanical pre-soaking provides a simple strategy to modulate and diversify the descriptive sensory profile of Lampung Robusta coffee while preserving its intrinsic identity, offering directional insights for product optimization.

Keywords— **botanical pre-soaking, CATA, Lampung Robusta coffee, sensory profile, tamarind**

INTRODUCTION

Robusta coffee accounts for the largest share of Indonesia's coffee production, with Lampung recognized as one of the country's major Robusta-producing regions. Despite its substantial production volume, the commercial value of Robusta coffee beans remains lower than that of Arabica coffee. This condition is mainly associated with the sensory characteristics of Robusta coffee, which are generally dominated by bitterness and display lower sweetness and acidity than those of Arabica coffee (Liu *et al.*, 2019a; Moccand *et al.*, 2023). Consequently, improving the sensory quality of Robusta coffee has become an important strategy to increase its market competitiveness and added value.

Previous studies have demonstrated the potential of green bean soaking treatments to improve the aroma characteristics of Robusta coffee by modifying the composition of flavor precursors before roasting. Liu et al. (2019b) reported that soaking Robusta green coffee beans in a 2% acetic acid solution altered bean pH, significantly affecting aroma formation during roasting and modifying levels of pyrazines, furanic compounds, and sulfur-containing compounds ($p < 0.05$), enabling coffee blends containing up to 80% treated Robusta to exhibit no significant aroma differences from 100% Arabica coffee in sensory testing. In a subsequent study, Liu et al. (2019a) showed that pretreatment with a 15% fructose solution, which directly modified the concentration and availability of sugar precursors for Maillard and caramelization reactions, produced similar improvements, allowing blends containing up to 80% treated Robusta to be perceived as comparable to Arabica coffee in aroma, with the additional benefit of greater aroma stability over accelerated shelf-life storage.

Further advances in flavor modification were reported by Jo *et al*. (2023), that applied L-leucine powder pre-treatment to Robusta coffee beans using soaking and spraying-based approaches. Their study showed that selected treatments reduced volatile compounds associated with bitter aroma characteristics, particularly pyrazines, pyrroles, and phenols, thereby mitigating undesirable bitter-like aroma notes in Robusta coffee. In addition to pre-treatment approaches, roasting conditions play a critical role in flavor development because aroma generation during coffee roasting is governed by Maillard reactions, caramelization, sugar degradation, and pyrolysis (Tarigan, 2022). Current evidence supports the importance of roasting level and method in shaping sweet, caramel-like, or burnt aroma attributes (Obando & Figueroa, 2024).

The present study investigated the use of cinnamon, tamarind, and ginger solutions as botanical green coffee bean soaking agents before roasting. The selection of these botanical materials was based on their characteristic bioactive and volatile compounds that may contribute to desirable coffee flavor attributes. Cinnamon contains cinnamaldehyde, caryophyllene, and linalool, compounds associated with spicy and aromatic flavor enhancement. The addition of cinnamon to coffee has also been reported to improve sensory profile scores and overall taste perception (Tarigan *et al.*, 2023).

Tamarind is naturally rich in organic acids, particularly tartaric acid. Pretreatment of Robusta green beans with organic acids promotes the thermal formation of furfural and 5-methylfurfural during roasting, which are key volatile compounds associated with sweet, almond, caramel-like, and fruit-like flavor notes (Lee *et al.*, 2023). Meanwhile, ginger contains gingerols, shogaols, and zingerones, which contribute spicy flavor notes and enhance aroma in beverages (Maulida *et al.*, 2024). Furthermore, prolonged traditional roasting is expected to promote caramelization, which may enhance sweetness perception in Robusta coffee beverages, provided that roasting intensity is carefully controlled to avoid burnt notes (Abubakar *et al.*, 2024).

The botanical pre-soaking treatments may modify the descriptive sensory characteristics of Robusta coffee by introducing or altering the availability of key water-soluble and volatile precursor compounds during green bean pretreatment. During soaking, these extracted botanical compounds may diffuse into and interact with the green coffee bean matrix, thereby subsequently influencing reaction pathways and aroma and flavor development during thermal roasting and brewing.

To evaluate the overall effectiveness of these botanical soaking treatments, sensory profiling is required to determine consumers' perceptions and preferences for the resulting coffee beverages. The Check-All-That-Apply (CATA) approach is a sensory evaluation method widely used for this purpose, as it is simple, fast, and versatile, enabling the identification of sensory attributes perceived by untrained panelists and the assessment of consumer liking patterns (Silva *et al.*, 2025). Studies have demonstrated that CATA gives consistent result with conventional descriptive analysis, making it a reliable alternative for profiling sensory differences in coffee beverages (Wang *et al.*, 2023; Yoon *et al.*, 2023).

Therefore, this study aimed to investigate the sensory profile of Lampung Robusta coffee subjected to botanical pre-soaking treatments using cinnamon, tamarind, and ginger solutions, combined with traditional roasting methods, with particular emphasis on changes in perceived aroma and flavor characteristics, including attributes related to aroma complexity, flavor quality, and sweetness-associated notes. The study hypothesized that botanical pre-soaking would modify the descriptive sensory profile of Robusta coffee and increase the occurrence of desirable aromatic, flavor, and sweet-associated attributes compared with untreated Robusta coffee.

MATERIALS AND METHODS

Sample Preparation

The overall preparation procedure of the botanical pre-treated coffee samples is illustrated in Figure 1. The process consisted of six sequential stages, including extraction of botanical compounds, immersion of green coffee beans, drying, roasting, resting, and brewing.

First-grade Robusta green coffee beans, naturally processed and from Ulubelu District, Tanggamus Regency, Lampung Province, Indonesia, were used in this study. Botanical extracts were prepared separately using cinnamon (*Cinnamomum burmannii*) dried bark cinnamon sticks, ginger (*Zingiber officinale*) fresh ginger, and tamarind (*Tamarindus indica*) fresh tamarind.

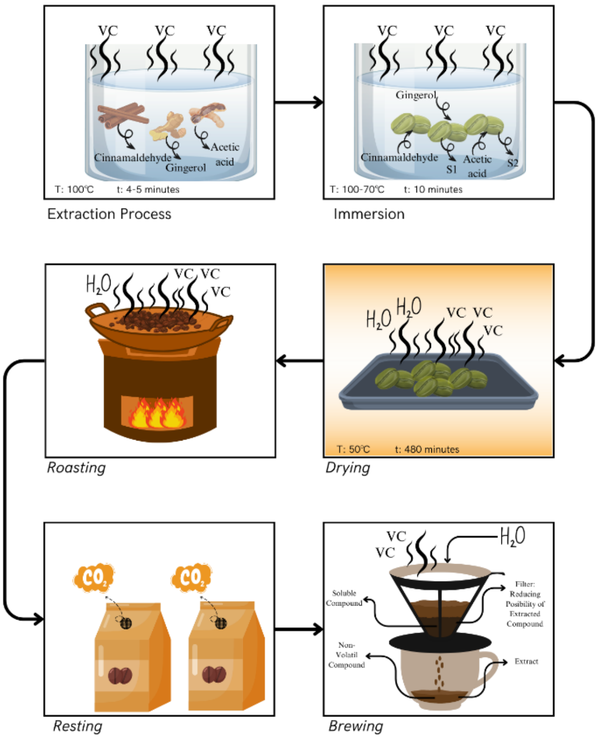

Figure 1. Experimental workflow for botanical pre-treatment of Robusta coffee beans prior to roasting and sensory evaluation.

Each spice was boiled in water at 100-70 °C for 4–5 min to extract water-soluble and potentially volatile compounds. The resulting extracts were subsequently used as soaking solutions for the green coffee beans.The freshly prepared botanical extracts were used immediately as soaking media. The green coffee beans were immersed in the respective botanical extracts at approximately 100 °C for 10 min, using a 1:1 ratio of green coffee beans to extract (w/v). During soaking, water-soluble compounds from the botanical extracts may diffuse into the green coffee beans along concentration gradients, while soluble compounds naturally present in the beans may simultaneously migrate into the soaking medium. However, the actual transfer or absorption of specific botanical compounds into the beans was not measured in this study.

Each treatment was prepared as a single processing batch; therefore, no independent processing replicates were performed (n = 1 processing batch per treatment). However, all samples were prepared using predetermined processing parameters, including the botanical material-to-water ratio, soaking temperature and duration, drying temperature and duration, and roasting conditions. The same specified processing conditions were applied consistently across the experimental treatments. Consequently, the present study evaluates sensory differences among samples produced under the specified processing conditions rather than estimating variability among independent processing batches.

Following immersion, the treated green coffee beans were removed from the respective botanical extracts and dried in a hot-air dryer at 50 °C for 480 min (8 h). The final moisture content of the dried green coffee beans was determined using the oven-drying method. The moisture content was measured after drying to verify that the beans had reached the targeted moisture range of approximately 11–13%**.**

The dried beans were then roasted using a traditional open-roasting technique in a clay pan heated over a wood-fired stove for approximately 110 min. The roasting temperature was approximately 160–180 °C, and the beans were continuously stirred manually to promote relatively uniform heat exposure. The roast degree was classified as medium-to-dark based on visual comparison of the roasted beans with reference coffee beans roasted to a similar degree at a local roastery. No instrumental roast-degree measurement, such as Agtron value or colorimeter measurement, was performed.

Because roasting was conducted manually using a wood-fired stove, variation in heat exposure and roast degree could not be completely controlled. Therefore, differences in roast degree may represent a potential confounding factor when interpreting sensory differences among the treatments. Any interaction between roasting reactions and botanical-derived compounds was considered a potential mechanism but was not directly measured in the present study.

After roasting, the coffee beans were allowed to rest for 3–5 days in sealed packaging to permit the gradual release of carbon dioxide (CO_2) produced during roasting and to stabilize volatile aroma compounds. This resting period is important for improving flavor balance and preventing excessive degassing during brewing.

Finally, the roasted coffee beans were ground and brewed using the V60 pour-over method. A coffee-to-water ratio of 1:10 was used with medium-coarse ground coffee. Water at 88–93 °C was used, and the total brewing time was approximately 6 min. The same brewing conditions were applied to all coffee samples. The V60 brewing technique was chosen because its paper filter produces a distinct volatile and sensory profile characterized by higher percentages of caramel and flowery-related compounds, while minimizing the earthy and roasted notes associated with metal-filter methods. This brewing approach provides a consistent and reproducible extraction medium, as V60 demonstrates good sample grouping and is less dependent on operator skill compared to immersion or pressure methods (Santanatoglia *et al.,* 2023).

Sensory Evaluation

The prepared coffee samples were served as unsweetened Robusta coffee beverages. Each sample (15–20 mL) was presented in a transparent shot glass and identified using randomized three-digit codes. The samples were served at approximately 40 °C. Sensory evaluation was conducted with 32 untrained panelists (16 males and 16 females) aged 19–25 years. The relatively small sample size and narrow age range were determined by the availability of eligible coffee consumers in the vicinity of the campus and may limit the generalizability of the findings.

All participants were regular consumers of unsweetened black coffee and were therefore considered familiar with the sensory characteristics of coffee beverages. Participation was voluntary, and all participants received an explanation of the sensory evaluation procedures before signing a written informed consent form. No formal institutional ethics committee approval was obtained for this sensory evaluation.

Sensory profiling was performed using the Check-All-That-Apply (CATA) method, which enables consumers to select all sensory attributes they perceive in a product from a predefined list of descriptors and has been widely applied for rapid sensory characterization of food products (Ares & Jaeger, 2015). Before sample evaluation, panelists were first asked to identify the sensory characteristics they considered ideal for a Robusta coffee beverage. Subsequently, each coffee sample was evaluated, and panelists selected all applicable sensory descriptors perceived in the samples.

The descriptors were selected based on descriptors reported in previous studies and industry references (Kinasih *et al.,* 2021; Seniman Coffee, 2020; Setyani *et al.*, 2018). Each panelist evaluated all five coffee samples in randomized order. Between samples, the palate was cleansed with mineral water. Following the CATA assessment, overall consumer acceptance was measured on a 9-point hedonic scale, ranging from 1 (dislike extremely) to 9 (like extremely), with 5 indicating neither like nor dislike. The hedonic evaluation was conducted to complement the CATA sensory profile by providing information on overall liking. The liking scores were used as supplementary information.

Data Analysis

The sensory evaluation data were analyzed using XLSTAT 2023 (Addinsoft, Paris, France). For the CATA data, the citation frequency of each sensory descriptor was calculated as the number of panelists who selected the descriptor for each coffee sample. Cochran's Q test was performed separately for each descriptor to determine whether the citation frequencies differed significantly among the five coffee samples, using a significance level of $p < 0.05$ (David & Djamaris, 2018).

For descriptors showing significant differences in Cochran's Q test, multiple pairwise comparisons were performed using the critical difference procedure to identify which coffee samples differed from one another. The citation frequencies and p-values were used to characterize the sensory differences among the coffee samples.

Correspondence Analysis (CA) was performed using the CATA citation-frequency data to visualize the relationships between the coffee samples and the sensory descriptors. Principal Coordinates Analysis (PCoA) was also performed to visualize the similarities and dissimilarities among the sensory profiles of the coffee samples based on the CATA data.

The ideal sensory profile was determined from the sensory attributes selected by the panelists as ideal characteristics of a Robusta coffee beverage. The ideal point was calculated based on the frequency of selection of the ideal attributes, and the relationship between the coffee samples and the ideal profile was visualized in the sensory space.

RESULTS AND DISCUSSION

The sensory profiles of botanical pre-soaking treatments are presented in the sensory flavor wheels. The visual descriptors indicate that each treatment produced distinct descriptive sensory patterns; however, statistical analysis revealed that spice-assisted immersion did not result in statistically significant differences across individual sensory attributes of Robusta Lampung coffee.

As presented in Table 1, Cochran's Q test showed no statistically significant differences among the tested coffee samples across all 34 evaluated sensory descriptors ($p > 0.05$). These statistical outcomes demonstrate that while descriptive variations in aroma and flavor frequencies were observed visually, the botanical pre-soaking treatments did not significantly alter the selection proportions for color, aroma, flavor, body, or aftertaste. Consequently, the sensory characterization of the samples is evaluated from a descriptive frequency perspective.

Figure 2 presents the sensory flavor wheels of Robusta coffee produced from untreated beans (sample 159) and beans subjected to different botanical pre-soaking treatments prior to roasting, including cinnamon (sample 284), tamarind (sample 637), ginger (sample 742), and a combination of cinnamon, tamarind, and ginger (sample 897).

Overall, the botanical pre-soaking treatments had only a limited influence on the color, body, and aftertaste attributes, which remained generally consistent across all samples. In contrast, more pronounced descriptive variations were observed in the aroma and flavor profiles, where each botanical treatment generated distinct sensory descriptors while preserving the characteristic nutty, chocolate, and earthy notes of roasted Robusta coffee. The combined botanical treatment exhibited the greatest diversity of aroma and flavor descriptors, suggesting that interactions among the different botanicals contributed to a more complex sensory profile than individual treatments.

Sample 159 (untreated control) was characterized by a rich combination of aroma and flavor attributes, including nutty, caramel, fruity, dark chocolate, and spicy notes (cinnamon, nutmeg, clove, and ginger). The brewed coffee exhibited a cinnamon-like color and a predominantly light body with a slight bold perception, attributable to the V60 pour-over brewing method, which produces a clean cup while retaining soluble compounds that contribute to mouthfeel. The bitter and astringent aftertaste reflects the inherent chemical composition of Robusta coffee, particularly its high levels of caffeine and chlorogenic acids. These sensory observations are comparable to those reported by Asiah et al. (2025), where traditional open roasting on a clay pan over firewood produced sensory characteristics resembling City, Full City, and Italian roast profiles obtained from modern closed-system drum roasters.

Table 1. Cochran's Q Test on the Sensory Attributes of Robusta Coffee

Attributes	p-values
Cinnamon Colors	0.310
Roasted Almond Colors	0.573
Dark Colors	0.657
Earthy Aroma	0.745
Green Aroma	0.255
Nutty Aroma	0.483
Dark Chocolate Aroma	0.885
Fruity Aroma	0.144
Caramel Aroma	0.528
Ginger Aroma	0.349
Pepper Aroma	0.695
Nutmeg Aroma	0.663
Cinnamon Aroma	0.349
Tamarind Aroma	0.393
Clove Aroma	0.929
Earthy Flavor	0.580
Salty Flavor	0.436
Green Flavor	0.287
Nutty Flavor	0.269
Dark Chocolate Flavor	0.273
Fruity Flavor	0.337
Caramel Flavor	0.278
Ginger Flavor	0.637
Pepper Flavor	0.061
Nutmeg Flavor	0.054
Cinnamon Flavor	0.119
Tamarind Flavor	0.635
Clove Flavor	0.406
Light Body	0.065
Bold Body	0.065
Astringent Aftertaste	0.831
Bitter Aftertaste	0.222
Spicy Aftertaste	0.222
Sweet Aftertaste	0.624

For sample 284 (cinnamon pre-soaking), the color, body, and aftertaste were generally comparable to those of the untreated coffee, exhibiting a cinnamon-like color, light body with a slight bold perception, and a typical bitter and astringent aftertaste. The aroma was characterized by dark chocolate, nutty, tamarind, cinnamon, caramel, earthy, and several spicy notes (clove, ginger, pepper, and nutmeg), indicating that cinnamon pre-soaking enhanced spice-related aromatic complexity while preserving the inherent roasted characteristics of Robusta coffee.

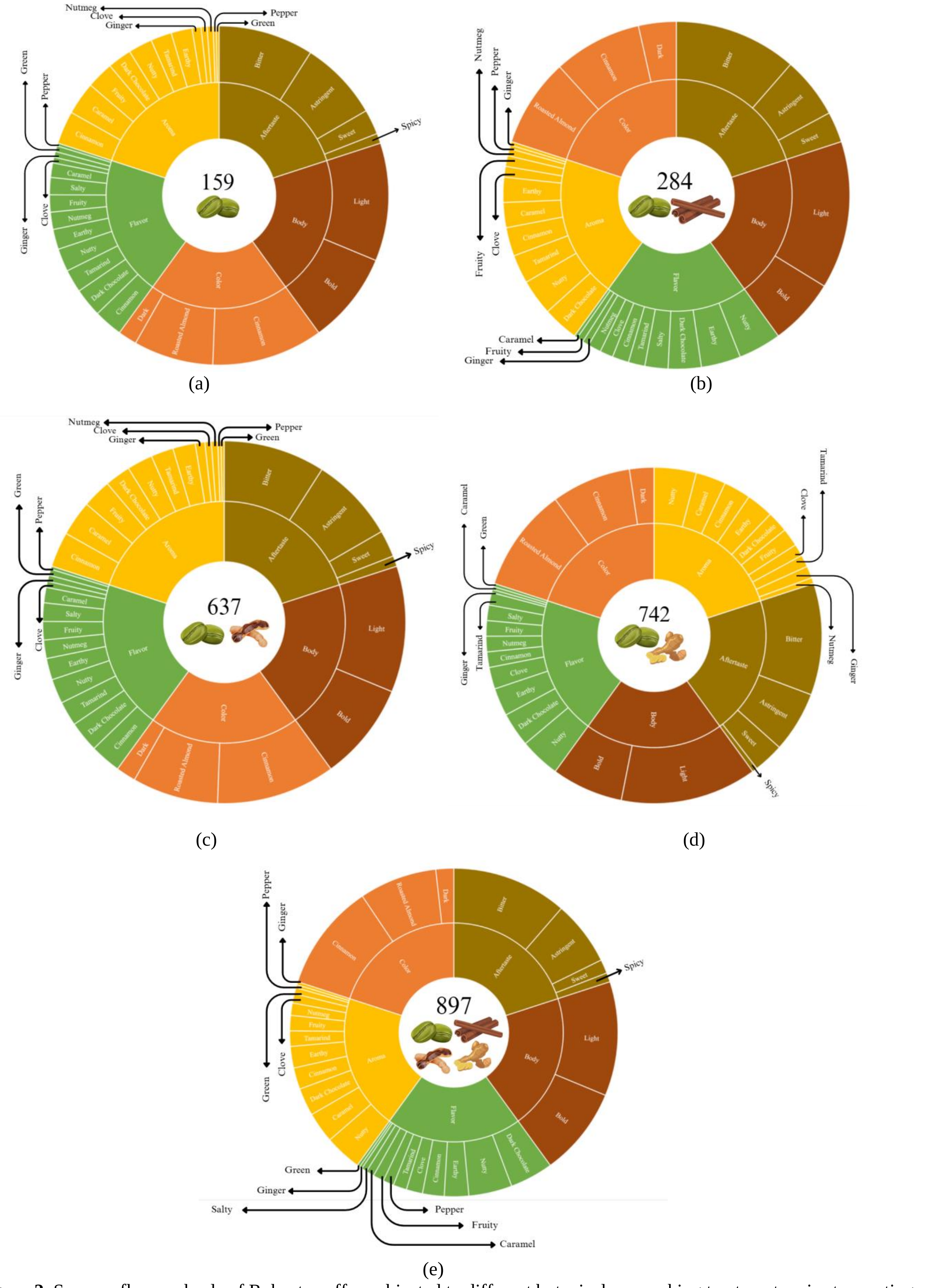

Figure 2. Sensory flavor wheels of Robusta coffee subjected to different botanical pre-soaking treatments prior to roasting. (a) Sample 159 = untreated (control); (b) sample 284 = cinnamon pre-soaking; (c) sample 637 = tamarind pre-soaking; (d) sample 742 = ginger pre-soaking; (e) sample 897 = combined cinnamon, tamarind, and ginger pre-soaking.

Similarly, the flavor profile was dominated by nutty, earthy, dark chocolate, salty, tamarind, cinnamon, clove, and nutmeg, with subtle ginger, fruity, and caramel notes, producing a warm and well-balanced flavor profile enriched with spice-derived attributes.

The aroma and flavor profiles of sample 637 (tamarind pre-soaking) displayed greater sensory complexity. The aroma was dominated by caramel, fruity, dark chocolate, nutty, tamarind, earthy, and cinnamon notes, accompanied by distinct spicy descriptors (ginger, clove, nutmeg, and pepper) and a subtle green note. Compared with the cinnamon-treated sample, the tamarind treatment exhibited a relatively stronger fruity and caramel character while maintaining desirable roasted and spicy notes. This enhanced fruity and caramel-like profile aligns closely with the mechanistic pathway described by Lee et al. (2023), that onstrated that pre-soaking green coffee beans in organic acid solutions, such as tartaric acid naturally present in tamarind may promotes the thermal formation of furfural and 5-methylfurfural during roasting, leading to sweet, almond, and fruit-like flavor characteristics.

Sample 742 (ginger pre-soaking) exhibited a distinctive spice-forward sensory profile characterized by prominent ginger, nutmeg, and clove descriptors alongside nutty, dark chocolate, earthy, caramel, and fruity notes, with a subtle green nuance. Meanwhile, sample 897 (combined cinnamon, tamarind, and ginger) generated a complementary interaction among the three botanicals. Cinnamon contributed warm sweet-spicy characteristics, tamarind enhanced fruity and caramel-like notes, and ginger intensified spicy attributes, resulting in a balanced and multidimensional sensory profile without altering the intrinsic body and aftertaste of Robusta coffee.

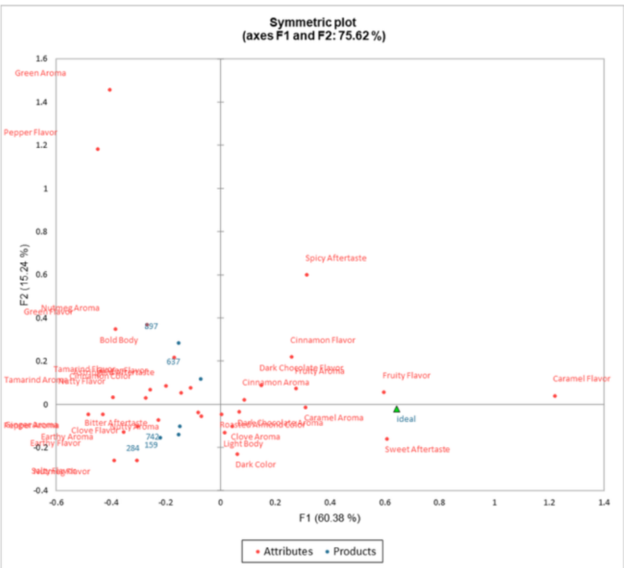

Figure 3. The relationship among coffee samples, sensory descriptors, and the ideal sensory profile using Correspondence Analysis (CA), where the first two dimensions explain 75.62% of the total variation (F1 = 60.38%; F2 = 15.24%).

In a symmetric CA biplot, spatial distances between sample points and attribute points represent directional and angular relationships rather than direct Euclidean distances. The ideal sensory point is located on the positive side of F1, positioned close to desirable attributes such as fruity flavor, sweet aftertaste, caramel aroma and dark color.

Conversely, all evaluated product samples (159, 284, 637, 742, and 897) are situated on the negative side of F1, indicating that no treated sample fully reached the ideal sensory profile. Directionally, sample 637 exhibits the highest coordinate value along the positive F1 axis among all product samples, placing it relatively closer to the ideal profile quadrant than the control or other botanical treatments, although a substantial sensory gap remains. The spatial separation between the tested samples and the ideal point suggests potential directions for sensory optimization, particularly by enhancing desirable fruity, caramel, sweet, and warm-spicy notes while moderating green, peppery, earthy, and bitter attributes (Meullenet *et al.*, 2008).

Furthermore, while acidity modulation was initially hypothesized as a potential benefit of tamarind soaking, acidity attributes were not selected by panelists as differentiating CATA terms, suggesting that sweetness perception was primarily manifested through caramel and sweet-aftertaste attributes.

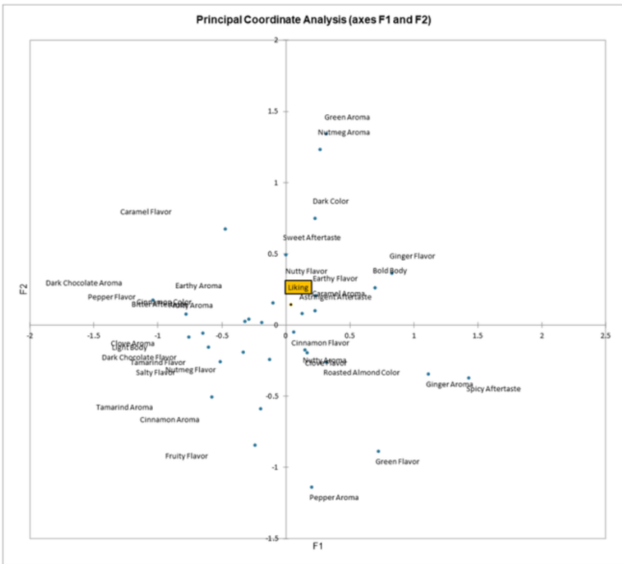

Figure 4. Principal Coordinate Analysis (PCoA) illustrating the association between sensory attributes and overall liking of botanical pre-soaked Robusta coffee samples.

Figure 4 shows the Principal Coordinate Analysis (PCoA) relating overall liking to sensory attributes of the botanical pre-soaked Robusta coffee samples. Liking is positioned near the center of the sensory space (slightly toward the positive F1 and F2 directions), indicating that consumer preference was not driven by a single dominant sensory note, but rather by a balanced combination of several familiar coffee attributes. The attributes located relatively close to liking included sweet aftertaste, nutty flavor, caramel aroma, astringent aftertaste, earthy flavor, and bold body. In particular, the close proximity of sweet aftertaste and nutty flavor to the liking position suggests that a harmonious combination of sweetness-associated notes and traditional nutty characteristics plays a central role in driving overall consumer acceptance.

In contrast, several attributes were positioned relatively far from the liking point, indicating weaker associations with consumer preference. Green aroma and nutmeg aroma were strongly separated along the positive F2 direction, while pepper flavor, bitter aftertaste, dark chocolate descriptors, and tamarind flavor/aroma were predominantly distributed toward negative F1. Interestingly, ginger aroma and spicy aftertaste were also clearly separated from liking despite being situated on the positive side of F1. This pattern indicates that the presence of intense or highly distinctive botanical spice characteristics does not automatically translate into higher acceptance, as excessive spice intensity may shift the coffee's intrinsic sensory identity. Consequently, consumer preference depends more strongly on achieving an appropriate balance among familiar coffee attributes and botanical-derived notes than simply maximizing the intensity of added spices, which aligns with consumer liking patterns reported by Guinard et al. (2023)

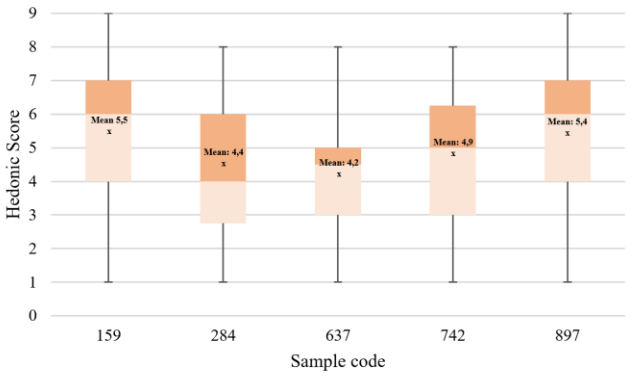

Figure 5. Hedonic score of Robusta coffee subjected to different botanical pre-soaking treatments prior to roasting. Sample 159 = untreated (control); sample 284 = cinnamon pre-soaking; sample 637 = tamarind pre-soaking; sample 742 = ginger pre-soaking; and sample 897 = combined cinnamon, tamarind, and ginger pre-soaking.

Figure 5 shows hedonic evaluation of Robusta coffee subjected to different botanical pre-soaking treatments prior to roasting, indicating moderate overall acceptance across all coffee samples, with no statistically significant differences in liking scores among treatments ($p > 0.05$). Broad rating distributions (ranging from 1 to 9) highlight substantial consumer heterogeneity, which is commonly observed in sensory assessments of *Coffea canephora* beverages. Such variability is consistent with the heterogeneous consumer responses reported for *Coffea canephora*, in which different consumer groups showed distinct acceptance patterns toward Robusta coffee beverages (Viencz *et al.*, 2024).

The moderate acceptance may partly reflect the sensory characteristics of Robusta coffee, which can include pronounced roasted, bitter, and sour attributes. In addition, the relatively young panelists (19–25 years) may have contributed to the variability in liking because consumer characteristics and coffee familiarity can influence hedonic responses. Importantly, age should be considered only as a possible contributing factor, since its specific effect was not tested in the present study. Previous research has demonstrated that consumer characteristics can be associated with different preferences for sensory profiles of Robusta coffee (Artêncio & Cassago, 2023).

Overall, the absence of significant differences indicates that botanical pre-soaking did not significantly affect overall liking, despite numerical differences in the mean scores. The presence of both very low and very high individual ratings further suggests that consumer heterogeneity may have been more influential than the treatment itself. Therefore, the sensory impact of the botanical treatments may be better explained by examining specific aroma and flavor attributes and their relationship with consumer preference rather than hedonic scores alone. This is particularly relevant because botanical additions have been shown to modify the sensory profile of Robusta coffee while generating different preference patterns among consumers (Shafaningrum *et al.*, 2026).

CONCLUSIONS

Botanical pre-soaking primarily influenced the aroma and flavor characteristics of Robusta coffee, while its effects on color, body, and aftertaste were comparatively minor. The treatments introduced distinctive botanical-derived notes without eliminating the typical nutty, chocolate, and earthy characteristics of roasted Robusta coffee, indicating that the intrinsic coffee profile was generally retained. Differences among treatments also demonstrated that the type of botanical material played an important role in shaping sensory complexity. In particular, sample 637 (tamarind pre-soaking) exhibited a diverse sensory profile characterized by fruity, caramel, dark chocolate, nutty, earthy, and tamarind notes accompanied by several warm-spice nuances. This profile suggests that tamarind pre-soaking promoted a broader integration of sweetness-associated, fruity, roasted, and spicy sensory characteristics.

The sensory mapping further demonstrated that the ideal coffee profile was oriented toward fruity, caramel-like, sweet, chocolate, and cinnamon-related characteristics. Directionally, sample 637 showed the closest positioning toward this ideal profile along the F1 axis, although a substantial sensory gap remained as all evaluated samples were situated on the negative F1 side. However, the liking analysis indicated that sensory acceptance was associated with a balanced combination of attributes rather than the dominance of any single flavor or aroma note. Taken together, these findings demonstrate the potential of botanical pre-soaking as a simple approach to modulate and diversify the sensory profile of Robusta coffee while maintaining its characteristic sensory identity. Future optimization should therefore focus on balancing desirable botanical-derived notes with the inherent characteristics of roasted Robusta coffee to achieve a profile that more closely approaches both sensory ideality and consumer preference.

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